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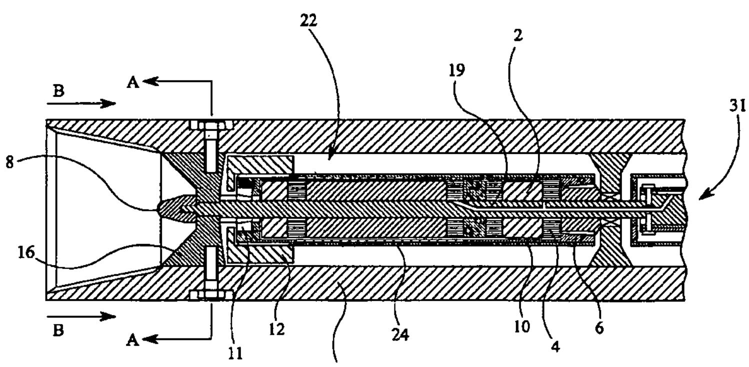
(54) Title: DOWNHOLE COMMUNICATION SYSTEM



(57) **Abstract:** A communication system for down hole use wherein information is relayed from a surface of a geological formation being drilled to down hole instrumentation (41). The system comprises: means for creating a series of changes in flow rate of a fluid being pumped down hole from the surface; an alternator (22) disposed down hole and rotatable in response to the fluid moving past the alternator (22); a torque generating apparatus (2, 10) which generates torque in response to the electrical output of the alternator (22) and which is mechanically connected to the alternator (22) for transmitting such torque to the alternator (22) for regulating rotatA communication system for down hole use wherein information is relayed from a surface of a geological formation being drilled to down hole instrumentation (41). The system comprises: means for creating a series of changes in flow rate of a fluid being pumped down hole from the surface; an alternator (22) disposed down hole and rotatable in response to the fluid moving past the alternator (22); a torque generating apparatus (2, 10) which generates torque in response to the electrical output of the alternator (22) and which is mechanically connected to the alternator (22) for transmitting such torque to the alternator (22) for regulating rotation thereof; and means (45) responsive to an electrical output of the alternator (22) for converting a series of changes in the flow rate of the fluid into instructions for down hole instrumentation (41).

DOWNHOLE COMMUNICATION SYSTEM

This invention relates to a communication system for down hole use in drilling applications. More particularly the invention relates to the use of a communication system for relaying information from a surface of a geological formation being drilled to down hole instrumentation.

In oil field drilling applications, communication between the surface and drilling instrumentation is an important requirement. The main requirement has been for down hole instrumentation to be able to transmit, for example by telemetry, survey data and various parameters of a geological formation being drilled back to the surface.

However, it is becoming just as important to be able to communicate from the surface to instrumentation down hole in order that drilling parameters and instructions can be dynamically changed.

There are two known methods of achieving the downward, surface to down hole telemetry.

The first method of downward communication uses strong electromagnetic fields at the surface to electrically communicate with the down hole instrumentation.

The second method of downward communication uses changes in the flow rate of drilling mud pumped down the centre of a drill collar to communicate encoded instructions to the drilling instrumentation. This method of communication is only applicable when the drilling instrumentation is powered by a mud alternator.

Down hole mud alternators are used to generate electrical power for down hole drilling instrumentation. Down hole alternators derive their primary power from a mud turbine, which rotates in response to the linear flow of the mud down the centre of the drill string. The drilling mud is pumped down from the surface by powerful pumps to perform a number of duties, for example drill string lubrication, formation coating, drill bit cooling and removal of drill cuttings back to the surface.

By applying a step change to the mud flow rate, there is a corresponding change in the speed of rotation of the alternator. The speed of rotation of the alternator is monitored by sampling a sine wave generated by a phase of the alternator. By measuring the frequency of the sine wave, the speed of rotation of the alternator can be calculated. A change in alternator speed causes a change in the frequency generated by the alternator. Changes in alternator frequency are converted into corresponding voltage changes and the voltage changes can be read by the down hole instrumentation. By encoding new drilling instructions into changes in mud flow rate, the down hole drilling instrumentation may be programmed with new drilling instructions from the surface. This is an important procedure as it allows the down hole drilling instrumentation to be reprogrammed without the need to remove it from the hole, which is an expensive and time consuming operation.

However, the use of the method of communication by means of mud flow rate pulsing using an alternator involves changing the speed of the alternator rotation away from a correct speed which is required to prevent potential problems. An alternator that rotates too quickly generates too much voltage for the down hole apparatus and consequently causes the apparatus to overheat. If an alternator causes the

apparatus to overheat for too long, the apparatus is likely to fail resulting in a costly interruption of the drilling programme. Therefore, additional down hole to surface communication is required to confirm that the alternator speed has returned to the correct value after the downward transmission of instructions.

The need to convert the changes in alternator frequency into readable changes in voltage for relaying the drilling instructions can lead to the hereinabove method being unreliable, as relatively small errors occurring during the frequency/voltage conversion stage can corrupt an intended message and prevent the message from being received correctly by the down hole instrumentation.

It is an object of the present invention to provide a communication system for down hole use capable of overcoming at least some of the above problems.

According to the present invention there is provided a communication system for down hole use wherein information is relayed from a surface of a geological formation being drilled to down hole instrumentation, the system comprising: means for creating a series of changes in flow rate of a fluid being pumped down hole from the surface; an alternator disposed down hole and rotatable in response to the fluid moving past the alternator; a torque generating apparatus which generates torque in response to the electrical output of the alternator and which is mechanically connected to the alternator for transmitting such torque to the alternator for regulating rotation thereof; and means responsive to an electrical output of the alternator for converting a series of changes in the flow rate of the fluid into instructions for down hole instrumentation.

The torque generating apparatus may comprise a first assembly including a generally cylindrical member of magnetically soft material and having a longitudinal axis, a second assembly arranged coaxially within the first assembly and including an electromagnetic winding, the first assembly and the second assembly being rotatable relative to each other about the axis, the arrangement being such that relative rotation between the first and second assemblies induces a magnetic field which generates rotational torque between the first and second assemblies.

A "magnetically soft material" is a material which is not capable of being substantially permanently magnetised, but which becomes magnetised whilst in an externally applied magnetic field.

Rectification means may be provided to convert the electrical output from the alternator to provide D.C. current to the electromagnetic winding of the torque generating apparatus to generate an electromagnetic braking effect.

Changes in the D.C. current to the electromagnetic winding of the torque generating apparatus may be utilised as the means for converting the series of changes in flow rate of the fluid past the alternator into instructions for the down hole instrumentation.

Down hole detection means, for example a microprocessor circuit, may be provided to detect the changes in the D.C. current.

The microprocessor circuit may comprise means, for example at least one preprogrammed look up table, to convert the changes in D.C. current into the instructions for the down hole instrumentation.

The first assembly may be a rotor assembly of the apparatus for producing rotational torque and the second assembly may be a stator assembly of the torque generating apparatus.

The second assembly may comprise a magnetically soft steel.

The first and second assemblies may be separated by a narrow gap.

The first assembly may be disposed so as substantially to surround the second assembly.

The first assembly may be substantially solid or may be formed from a plurality of laminations.

The second assembly may be substantially solid or may be formed from a plurality of laminations.

The first and second assemblies may define therebetween a substantially annular space for the passage of a fluid.

The torque generating apparatus may comprise a plurality of longitudinal grooves provided in an inside surface of the cylindrical member, the longitudinal grooves may be adapted to prevent an aggregation of particulate matter from the fluid flowing between the first and second assemblies.

The grooves may be provided so as to form at least a partial helix around the longitudinal axis of the first assembly.

The second assembly may be provided with a number of pole pieces extending generally radially from the longitudinal axis thereof. The pole pieces of the second assembly may be provided with an electromagnetic winding, adjacent poles being magnetisable in opposite directions. Means may be

provided to control the degree of the magnetisation. Gaps between the pole pieces may be filled with a potting material. The surface of the second assembly may be covered with a layer of soft magnetic or non magnetic material.

The first assembly may be provided with external rotation means such as impeller means adapted to rotate the first assembly, the impeller means being adapted to be disposed in use within the moving fluid, the motion of the fluid acting upon the impeller means so as to rotate the first assembly.

The torque generating apparatus and the alternator may be provided on a common shaft.

The alternator may be provided with external rotation means, such as impeller means adapted to rotate the alternator, the impeller means may be adapted to be disposed in use within the moving fluid, the motion of the fluid acting upon the impeller means so as to rotate the alternator. The impeller means may be an integral part of a magnet carrier of the alternator.

The electrical output of the alternator may be connected directly to the electromagnetic winding of the torque generating apparatus or may be connected indirectly by way of alternator voltage regulation means to create the electromagnetic braking effect.

Where the electrical power of the alternator is connected directly to the electromagnetic winding of the torque generating apparatus, the electromagnetic braking effect may be modified by varying the resistance of the winding, for example with one or more external resistances or by changing the gauge of the winding wire, or by varying the gap between

the first and second assemblies of the torque generating apparatus.

Where the electrical output of the alternator is connected indirectly to the electromagnetic winding of the torque generating apparatus, the alternator voltage regulation means may function to provide a progressive braking effect and/or to effect braking at a predetermined set point. The predetermined set point may be determined by a switch mode controller. The predetermined set point may be variable.

The means for creating a series of changes in the flow rate of the fluid may comprise a means for varying the speed of at least one mud pump at the surface of the geological formation.

For a better understanding of the present invention and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the accompanying drawings which show schematically various embodiments of the present invention. The figures may not be to scale. In the drawings:

Figure 1 is a cross sectional view of an embodiment of a combination of an alternator and torque generating apparatus arrangement forming part of a communication system according to the present invention;

Figure 2 is an end view of the combination of Figure 1 looking in the direction of the arrow B;

Figure 3 is a cross sectional view of the combination of Figure 1 taken along the line A-A;

Figure 4 is a more detailed view of a stator shown in Figure 1;

Figure 5 shows two views of a stator pole piece;

Figure 6 is a cross section of the stator shown in Figure 4;

Figure 7 is an end view of the stator shown in Figure 4;

Figure 8 is a sectional view of a rotor shown in Figure 1;

Figure 9 is an end view of the rotor of Figure 8;

Figure 10 is an end view detail of the rotor and stator assembly;

Figure 11 is a cross sectional view of another embodiment of a rotor similar to that shown in Figure 1 showing a laminated structure;

Figure 12 is an end view of the rotor of Figure 11 with the end cap removed;

Figure 13 is a cross sectional detail of a rotor and stator assembly incorporating the rotor of Figures 11 and 12;

Figure 14 is a schematic drawing of a rectifying means used in the combination of Figure 1;

Figure 15 is a schematic drawing of an alternative rectifying means incorporating an alternator voltage regulator device used in the combination of Figure 1;

Figure 16 is a schematic of an arrangement means by which coding supplied to the alternator is relayed to down hole instrumentation; and

Figure 17 is a representation of coding schemes utilised with a communication system according to the present invention.

Figure 1 shows a combination of an alternator and a torque generating apparatus for down hole use in drilling applications. The torque generating apparatus comprises a second assembly in the form of a cylindrical stator (2). The stator (2) is shown in more detail in Figures 4 to 7. The stator is made of magnetically soft material and is provided with stator windings (4) arranged so that, when energised, the stator (2) is magnetised as discussed below. The stator is mounted on a fixed shaft (8). Surrounding the stator is a first assembly in the form of a magnetically soft steel rotor (10). The rotor (10) is mounted on the stator (2) by way of bearings (6, 11), such as thrust bearings. The rotor/stator assembly is contained within a cylindrical housing (14) which may typically be a section of drill collar. The assembly is supported by an anchor (16) which is bolted to the housing.

A three phase alternator (22) is provided on the same shaft as the torque generating apparatus. The alternator (22) and the torque generating apparatus share a common rotor.

The output voltage of the alternator is connected via rectification means (31) to the stator windings of the torque generating apparatus so that the torque generating apparatus provides negative feedback in the form of progressive braking as the rotational speed of the joint rotor assembly increases or when the rotational speed of the rotor exceeds a predetermined limit, as will be described later.

The stator windings (4) of the torque generating apparatus are connected to windings of the alternator by way of access holes (19) formed in the core of each apparatus as shown in Figure 1.

In use, the combination is disposed down hole, drilling mud being pumped down the hole in the direction indicated by arrows B. The moving drilling fluid acts on the impeller (12) so as to rotate the rotor (10).

Mud alternators, such as the illustrated alternator (22), are generally three phase electrical rotating machines connected to a full wave rectifier (31) to convert the three alternating current waveforms into a single direct current supply. A typical circuit diagram is shown in Figure 14. The impeller (12) is an integral part of a magnet carrier (24) of the alternator and spins at several thousand rpm in response to the flow rate of mud past the impeller. By electrically connecting the rectified output of the alternator (22) to the stator windings (4) of the torque generating apparatus, an electromagnetic brake is created between the torque generating apparatus and the alternator. Depending on the manner of the electrical connection, two different braking effects can be created as will be explained in more detail hereinafter.

Electrically connecting the stator windings (4) of the torque generating apparatus to the rectified output of the alternator (22) creates a progressive braking effect because the alternator (22) progressively energises the stator windings (4) with current. The greater the rectified alternator voltage, the greater the current flowing in the stator windings (4) and the greater the electromagnetic braking effect. The feedback loop created provides proportional control over the alternator output and the

maximum speed of the alternator (22) is controlled irrespective of the profile of the impeller (12) and the mud flow rate. Such an electrical connection provides the more simple method of speed control within the alternator assembly and may be fine tuned by varying either the resistance of the stator windings or the air/mud gap between the rotor and stator of the torque generating apparatus. The resistance of the stator windings (4) may be modified by adding external resistors in series with the stator windings, or by changing the gauge of wire used to construct the stator windings. The total resistance, and hence the braking control achieved by either method, may be determined by calculation. Changing the air/mud gap involves a grinding operation to increase the gap between the rotor and stator of the torque generating apparatus to reduce the braking effect.

Alternatively, as shown in Figure 15, the braking characteristics may be changed from proportional to any other form of control by providing an alternator voltage regulator device (33) between the alternator (22) and the torque generating apparatus. A switch mode controller is preferred to minimise losses within the alternator voltage regulator device.

An alternator voltage regulator device can be used to apply both linear and/or non linear braking characteristics to the alternator by way of the stator windings of the torque generating apparatus. A typical circuit, shown in Figure 15, comprises an alternator voltage regulator in the form of a programmable switch mode power supply deriving power from the rectified alternator output and supplying programmed power output to the stator windings (4) of the torque generating apparatus. A predetermined or programmable voltage sensitive trip device activates the switch mode power supply. Below the trip point, the alternator runs open loop and there is no

induction braking. Above the trip point, the loop is closed and induction braking is applied to the alternator. In this manner the set point between open loop and closed loop control can be programmed at any chosen location on the alternator speed curve and may be tuned to vary the output voltage and/or frequency according to the requirements of different customers.

By coupling the alternator to a torque generating apparatus, the alternator no longer operates open loop and can safely be left unattended down hole to monitor its own output. Manufacturers of down hole alternators need only provide one system for all customers instead of several impeller/alternator pairs for differing output power demands and variable mud flow rates. A single combined alternator and torque generating apparatus may be programmed to reproduce the output voltage profiles corresponding to different impellers by limiting the output voltage with induction braking. Such an arrangement reduces design and manufacturing costs, simplifies the operational needs of field engineers, and improves down hole reliability of the alternator and down hole instrumentation.

Figure 2 is an end view of the apparatus of Figure 1. It shows the fixed shaft (8), anchor (16) and the impeller blades (12). The direction of mud flow in Figure 2 is into the paper, causing rotation of the impeller blades.

Figure 3 shows a cross sectional view as indicated in Figure 1. The assembly anchor (16) is shown in cross section, bolted to the drill collar housing. The shaft (8) can be seen in cross section. The view in Figure 3 is looking inwards into the assembly in the direction of the incoming mud, and the impeller blades (12) can be seen behind the assembly anchor (16).

Figures 4 to 7 are more detailed views of the stator assembly. The stator (2) of the torque generating apparatus is a simple four pole electromagnet which forms the electrical and mechanical centre of the machine. The stator (2) has a central shaft from which radially project four pole pieces (35), as shown. The number of pole pieces need not be limited to four, any suitable number of pole pieces may be provided, larger machines requiring more pole pieces.

To prevent the stator (2) from being crushed by normal down hole drilling pressures, the gaps between the stator pole pieces may be filled with a high compressive strength material such as epoxy filler (not shown) to produce a solid, substantially cylindrical, stator. This allows the stator (2) to maintain its shape and survive pressures in excess of 20,000 pounds per square inch.

The stator (2) of the torque generating apparatus is wound with high temperature resistant enamelled copper wire (not shown in Figures 4 to 7) so as to produce alternate north and south magnetisation of the pole pieces. To preserve the integrity of the stator winding from the drilling mud, as shown in Figures 1 and 10 a thin sleeve of soft magnetic or non magnetic material (21) is machined to cover the stator windings. End cheeks provided on the stator receive the sleeve (21) and are welded thereto to seal the assembly. This seals the edges of the stator (2) and protects the contents from contamination. The covering, for example in the form of a cylinder, allows the stator poles to rotate with respect to the rotor (10) whilst maintaining close magnetic contact. A small magnetic gap is required to create the high output torque reactions from this machine.

An important feature of the apparatus is the use of electromagnetic advantage to minimise the power demands of

the stator (2). By its nature, this induction machine relies upon high rates of change of magnetic flux to effect braking in the rotor. High operating efficiency will therefore be achieved at high rotor RPM.

Figures 8 to 10 show the rotor (10) of the torque generating apparatus in more detail. Figure 10 shows the arrangement of the first and second assemblies define therebetween a substantially annular space for the passage of a fluid, for example drilling mud.

The rotor (10) consists of a simple steel cylinder having open grooves (20) machined to the inside surface. The grooves (20) perform two important functions. They allow the rotor (10) and stator (2) to maintain close magnetic contact and at the same time allow a sufficient flow of drilling mud through the annular space between the rotor and stator. This aids lubrication of the rotor bearings (6, 11) and allows dissipation of heat.

The grooves (20) also prevent mud particles from aggregating within the annular space and clogging the apparatus. If the annular space were too small, mud particles would become trapped due to low mud flow velocities. The mud particles would quickly aggregate, binding the stator (2) and rotor (10) and causing a down hole failure. In conventional down hole electrical apparatus, like alternators, which use a permanent magnet rotor, failure frequently occurs due to mud material becoming trapped and clogged within the space between the rotor and stator. The clogging problem is compounded by both soft and hard magnetic particles that circulate within the mud. Once trapped by the strong magnetic fields within the permanent magnet rotor, the magnetic particles capture non magnetic mud particles, accelerating clogging. The present apparatus avoids this

type of failure by providing a more generous space between rotor and stator (due to the grooves) in the area of the torque generating apparatus and by being composed of soft magnetic material which does not trap particles to the same extent as a permanent magnet.

An important feature of the torque generating apparatus is the use of electromagnetic advantage and a rotor to dissipate waste heat from work done by the apparatus. The induced currents circulating in the rotor (10) would give rise to I^2R heating in the rotor raising its working temperature. However, because the rotor (10) is manufactured from a magnetically soft material, its performance is unaffected by this temperature rise. It can therefore operate in temperatures much higher than the current limit of 180 degrees Celsius, without any loss of performance. In theory, the rotor (10) alone can operate at temperatures up to the Curie temperature of the permanent magnets.

According to another realisation of the rotor (10) of the torque generating apparatus, not shown in the figures, the grooves (20) are formed with a small flute or spiral twist along their length. In this way, every rotation of the rotor (10) produces a small pumping effect, pumping mud and contaminant particles through the apparatus. These features would expel hard and soft magnetic particles which would otherwise become trapped by the permanent magnets of the alternator.

The pole pieces of the stator (2) and the protruding portions of the rotor inner surface are disposed so as to correspond, being aligned (in the case of a four pole apparatus) every quarter turn of the rotor (10). As discussed, the number of pole pieces and protruding portions may be varied to suit a particular application. Although the rotor (10) and stator

(2) in this example are formed of magnetically soft steel, any suitable soft magnetic material may be employed. Similarly, the protective coating of the stator (2) may be made of ferrous or non ferrous material.

Normal use of the torque generating apparatus may erode the inner surface of the rotor (10) and/or the protective coating or outer surface of the stator (2). This would cause a gradual loss of output torque. The apparatus is, however, easy and economical to repair, as any mechanical errors may be easily corrected by welding, machining and/or grinding the relevant part.

Figures 11 to 13 show an alternative rotor (25) in more detail. The rotor (25) consists of a laminated steel cylinder having a number of conductors (29) running the length of the rotor (25). The conductors (29) are connected at each end of the rotor (25) by means of a conductor end cap (27). The arrangement of conductors (29) and end caps (27) form what is known as a squirrel cage conductor winding.

The conductors (29) and conductor end caps (27) consist of rods and plates of beryllium copper, which has a similar electrical resistivity to aluminium but is a stronger material, resistant to mechanical abrasion and chemical attack from drilling muds.

Figure 13 shows the arrangement of the first and second assemblies define therebetween a substantially annular space for the passage of a fluid, for example drilling mud.

A close magnetic contact is still maintained between the rotor (25) and the stator (2).

It should be understood that the stator which can be in a solid or laminated form can be used in conjunction with either a solid or laminated rotor.

The ability of the alternator to automatically regulate the speed of its rotor using the torque generating apparatus results in a current supplied by the alternator to the torque generating apparatus to provide the braking effect being exploitable for relaying instructions to the down hole instrumentation.

Figure 16 shows a schematic of an arrangement by which coding supplied to the alternator (22) is relayed to down hole instrumentation (41).

As described hereinbefore electrically connecting the stator windings (4) of the torque generating apparatus to the rectified output of the alternator (22) creates a progressive braking effect because the alternator (22) progressively energises the stator windings (4) with current. The greater the speed of rotation of the alternator, the greater the rectified alternator voltage, the greater the current flowing in the stator windings (4) and the greater the electromagnetic braking effect. The closed, feedback loop created provides proportional control over the alternator output and the maximum speed of the alternator (22) can be controlled irrespective of the mud flow rate by the use of an alternator voltage regulator device (33), for example a switch mode controller.

It has been found such an electrical connection enables encoded communication in the form of changes in mud flow rate to be relayed to down hole instrumentation. In response to changes in mud flow rate, an electrical output of the alternator in the form of the braking current (43) supplied

to the windings (4) of the torque generating apparatus is adjusted, i.e. increased or decreased, by the closed loop design and the alternator regulator (33) to maintain a constant alternator rotor speed and regulated output voltage.

Mud flow is essentially constant, but has a relatively small ripple content superimposed upon it by characteristics of the mud pumps. The closed loop properties of the arrangement of the alternator and torque generating apparatus constantly corrects for the ripples in the mud flow and compensates for the changes to achieve a regulated output voltage from the alternator.

By intentionally varying the mud flow rate in addition to the natural ripple level, for example by means of varying the speed of a surface mud pump, coded instructions may be transmitted down to the alternator (22) by means of time displaced changes in mud flow rate as shown in Figure 17. The changes in mud flow rate result in associated changes in the output of the alternator and consequently in the electromagnetic current of the windings (4) which reproduce the step changes in mud flow rate. The changes in the current are read by a microprocessor circuit (45) and the changes are decoded. The decoded instructions are passed on from the microprocessor circuit (45) to drilling instrumentation (41) using an internal data link (47).

Figure 17 is a representation of coding instructions in the form of time displaced changes in mud flow rate which can be used with a communication system according to the present invention. Changes in mud flow rate (61) are shown against time (63).

Due to the slow speed of surface to down hole telemetry, down hole drilling instrumentation is usually preprogrammed using

a look up table embedded into the memory of an associated microprocessor circuit. The look up table may, for example, be numbered 0 to 9 and each number defines a particular drilling operation or mode. Mode 0 is typically the default mode to which instrumentation reverts if there is any form of software failure. Modes 1 to 9 define other drilling characteristics required from the drilling instrumentation, for example drill at 30 degrees declination, drill horizontally, or drill 10 degrees to the right.

The microprocessor circuit (45) of the alternator (22) is prepared for new instructions with a synchronisation code (65) consisting of, for example, three mud flow pulses (67, 69, 71). The three mud flow pulses are detected by the microprocessor circuit as three equivalent changes in the current of the windings (4). The synchronisation mud flow pulses are produced by changing the flow rate of the mud being pumped down hole from the surface, for example between a low (75) of 500 gallons per minute to a high (73) of 600 gallons per minute. The flow rate of the mud is changed, for example, by varying the speed of the mud pumps at the surface.

Once the microprocessor circuit is prepared by the synchronisation code (65), the time interval between the last synchronisation pulse (71) and the next mud flow pulse (77) instructs the microprocessor circuit which mode the drilling instrumentation should adopt until instructed otherwise.

Examples of coding for instructing modes 1 to 9 to be adopted are represented in Figure 17 as 81 to 97 respectively.

By means of a third party flow restriction device, for example a poppet valve or a siren of a type known by a person skilled in the art, mud pulse telemetry can be used to

communicate from down hole to the surface and a drilling engineer at the surface can receive confirmation that new instructions have been implemented as the details concerning the new drilling characteristics will be transmitted along with survey data which is collected on a regular basis.

Electromagnetic telemetry may also be used to communicate confirmation of the implemented instructions from down hole to the surface.

Overall, the advantage of using an alternator with the ability to automatically regulate its rotor speed by means of the feedback loop involving the electromagnetic windings of the torque generating apparatus means that changes in mud flow rate can be used to send coded messages from the surface to the down hole drilling instrumentation without changing the speed of rotation of the alternator from the correct speed required to prevent potential problems, for example overheating.

The changes in braking current are directly related to the changes in mud flow rate, and the braking current changes relay the coded information to the microprocessor circuit. The possibility of any corruption of the coded message occurring is reduced and the instructions are communicated more reliably.

A microprocessor circuit (45) is described hereinbefore for reading the changes in the current of the windings (4) and decoding the instructions for the drilling instrumentation. It should be appreciated that other decoding means known to a person skilled in the art could be used.

CLAIMS

1. A communication system for down hole use characterised in that information is relayed from a surface of a geological formation being drilled to down hole instrumentation (41), the system comprising: means for creating a series of changes in flow rate of a fluid being pumped down hole from the surface; an alternator (22) disposed down hole and rotatable in response to the fluid moving past the alternator (22); a torque generating apparatus (2, 10) which generates torque in response to the electrical output of the alternator (22) and which is mechanically connected to the alternator (2) for transmitting such torque to the alternator (22) for regulating rotation thereof; and means (45) responsive to an electrical output of the alternator (22) for converting a series of changes in the flow rate of the fluid into instructions for down hole instrumentation (41).

2. A communication system as claimed in claim 1, characterised in that the torque generating apparatus comprises a first assembly (10) including a generally cylindrical member of magnetically soft material and having a longitudinal axis, a second assembly (2) arranged coaxially within the first assembly and including an electromagnetic winding (4), the first assembly (10) and the second assembly (2) being rotatable relative to each other about the axis, the arrangement being such that relative rotation between the first (10) and second (2) assemblies induces a magnetic field which generates rotational torque between the first (10) and second (2) assemblies.

3. A communication system as claimed in claim 2, characterised in that rectification means (31) is provided to convert the electrical output from the alternator (22) to provide D.C. current to the electromagnetic winding (4) of

the torque generating apparatus to generate an electromagnetic braking effect.

4. A communication system as claimed in claim 3, characterised in that changes in the D.C. current to the electromagnetic winding (4) of the torque generating apparatus are utilised as the means for converting the series of changes in flow rate of the fluid past the alternator (22) into instructions for the down hole instrumentation (41).

5. A communication system as claimed in claim 4, characterised in that down hole detection means (45) are provided to detect the changes in the D.C. current.

6. A communication system as claimed in claim 5, characterised in that the down hole detection means comprises a microprocessor circuit (45).

7. A communication system as claimed in claim 6, characterised in that the microprocessor circuit (45) comprises means to convert the changes in D.C. current into the instructions for the down hole instrumentation (41).

8. A communication system as claimed in claim 7, characterised in that the conversion means comprises at least one preprogrammed look up table.

9. A communication system as claimed in any one of claims 2 to 8, characterised in that the first assembly is a rotor assembly (10) of the torque generating apparatus for producing rotational torque and the second assembly (2) is a stator assembly of the torque generating apparatus.

10. A communication system as claimed in any one of claims 2 to 9, characterised in that the electrical output of the

alternator (22) is connected directly to the electromagnetic winding (4) of the torque generating apparatus to create the electromagnetic braking effect.

11. A communication system as claimed in any one of claims 2 to 9, characterised in that the electrical output of the alternator (22) is connected indirectly to the electromagnetic winding (4) of the torque generating apparatus by way of alternator voltage regulation means (33) to create the electromagnetic braking effect.

12. A communication system as claimed in claim 11, characterised in that the alternator voltage regulation means (33) functions to provide a progressive braking effect.

13. A communication system as claimed in claim 11, characterised in that the alternator voltage regulation means (33) functions to effect braking at a predetermined set point.

14. A communication system as claimed in any preceding claim, characterised in that the means for creating a series of changes in the flow rate of the fluid comprises a means for varying the speed of at least one mud pump at the surface of the geological formation.

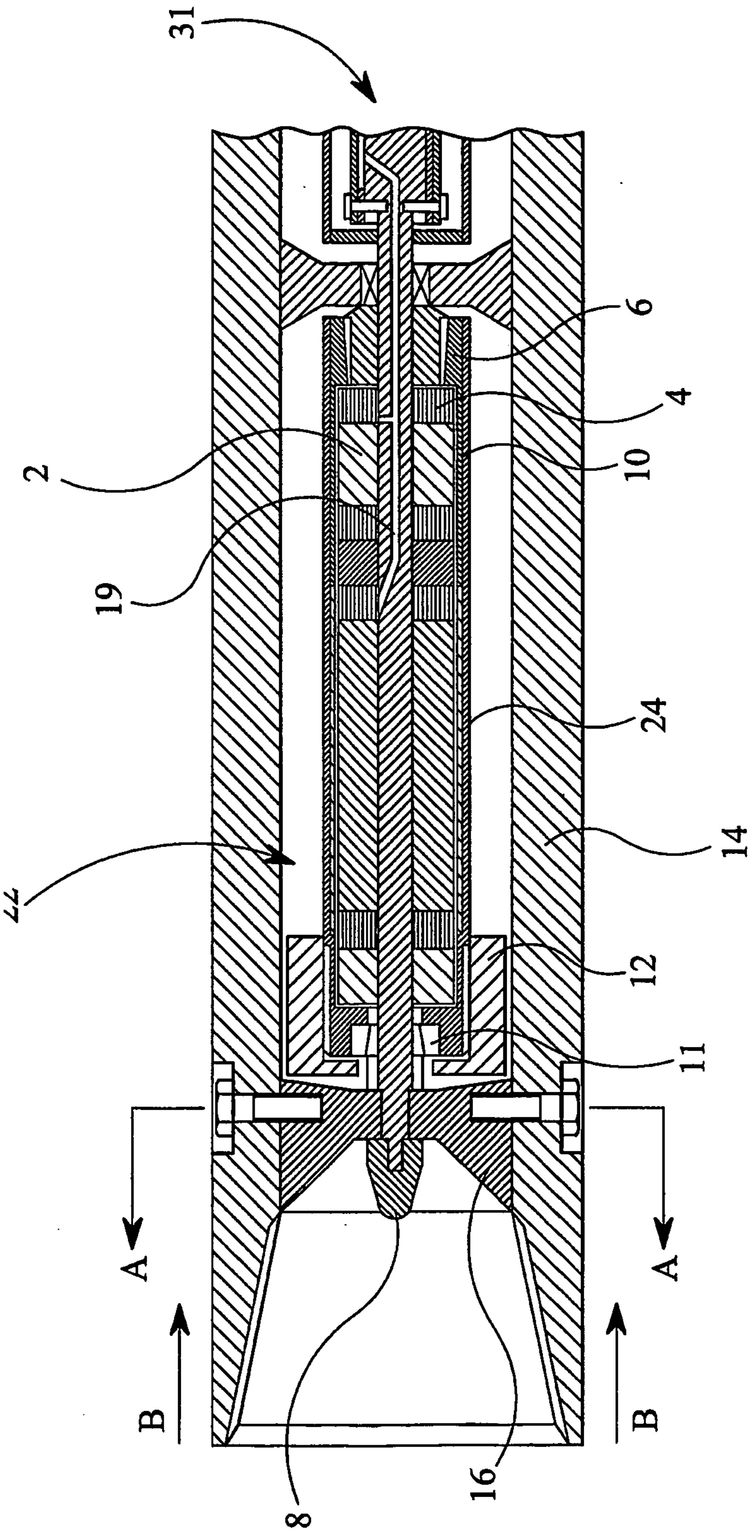
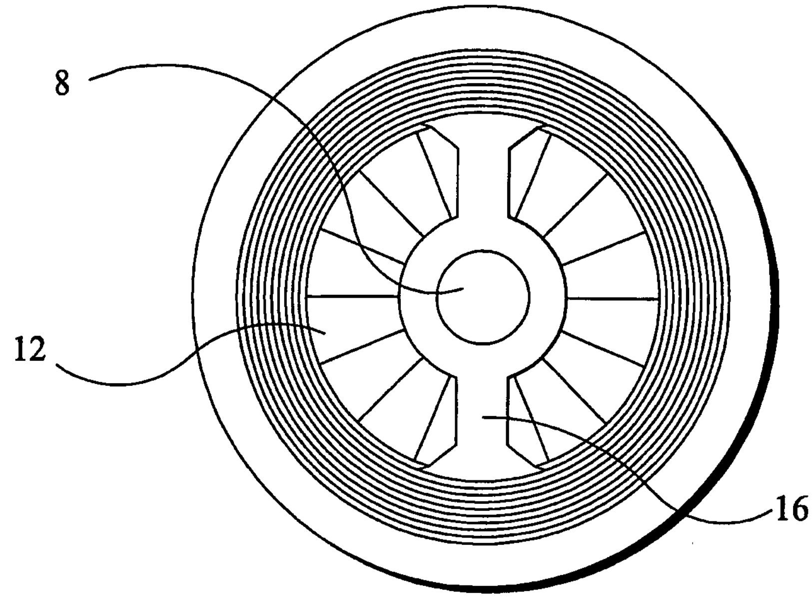


FIG 1

FIG 2



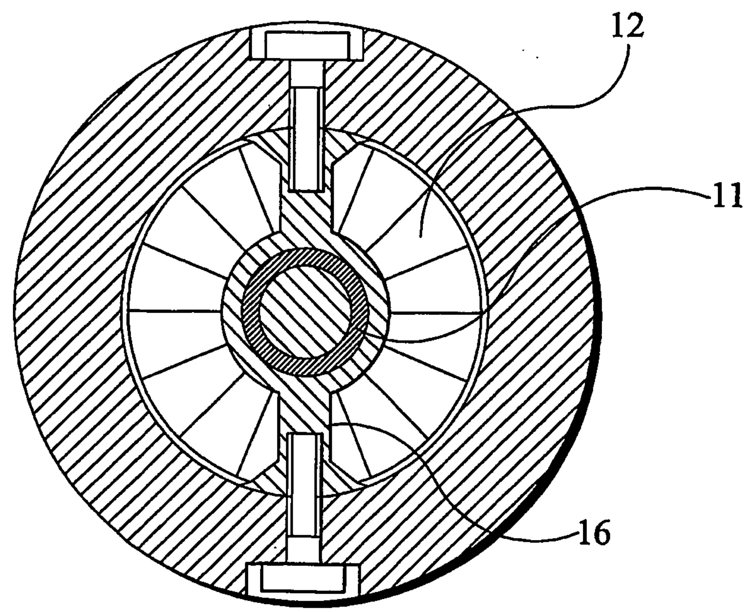


FIG 3

FIG 4

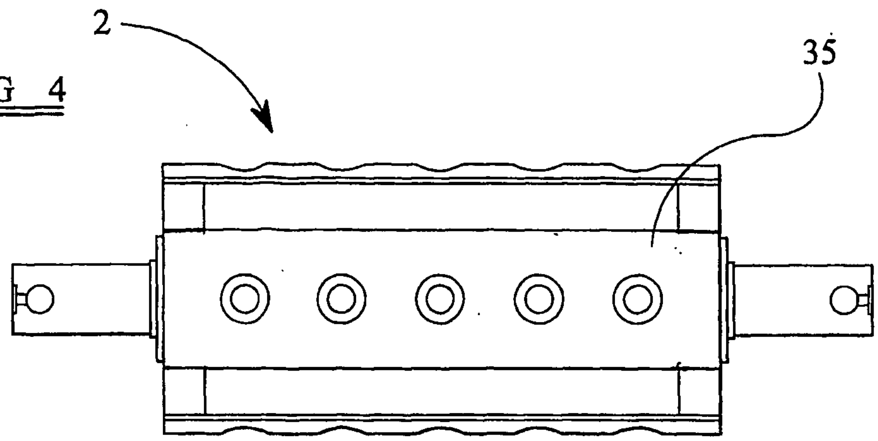
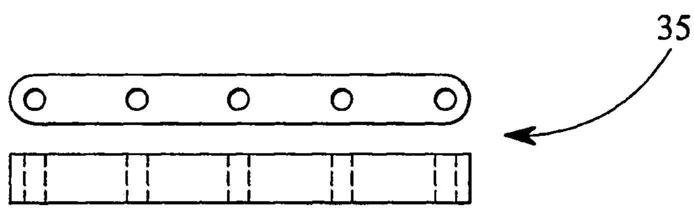


FIG 5



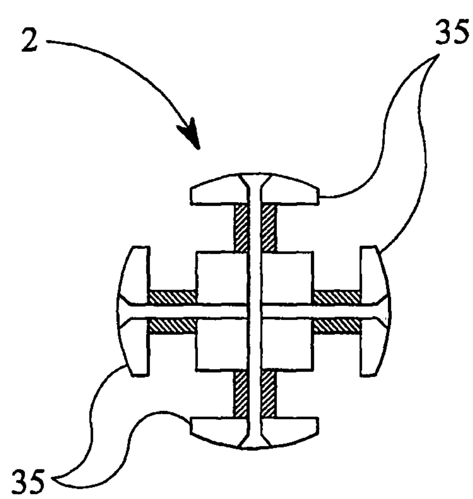


FIG 6

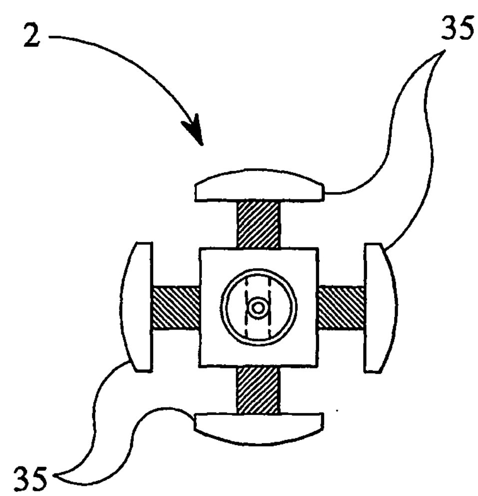


FIG 7

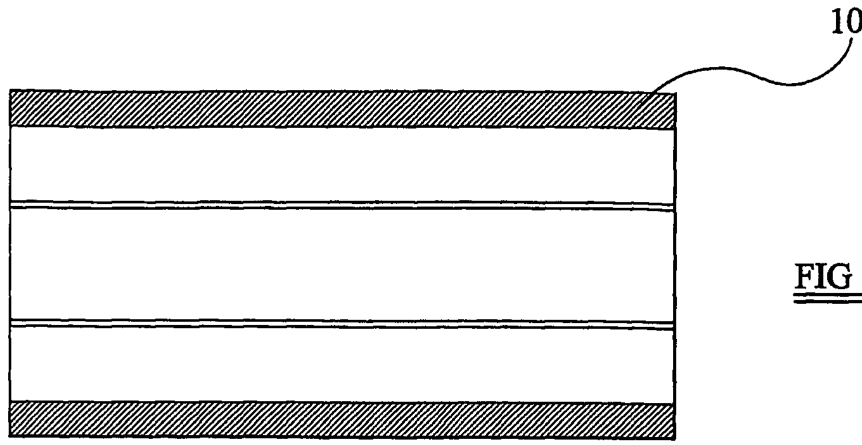


FIG 8

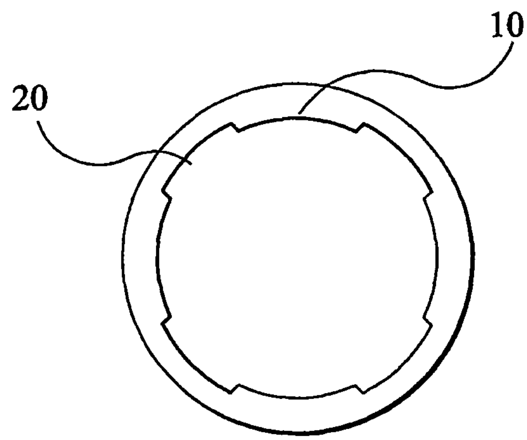


FIG 9

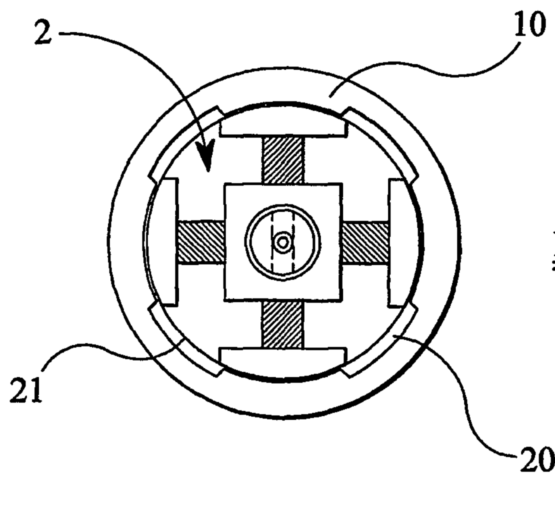
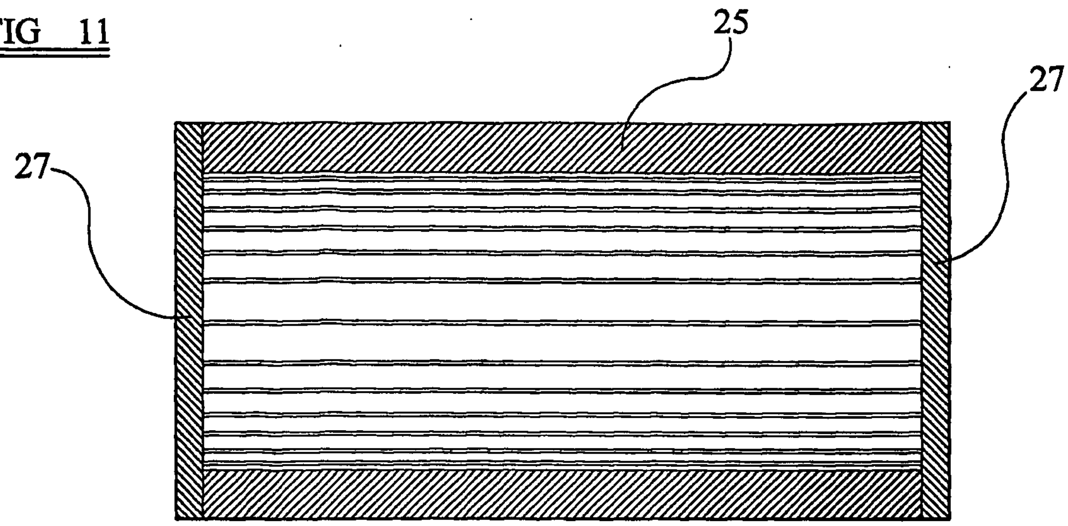


FIG 10

FIG 11



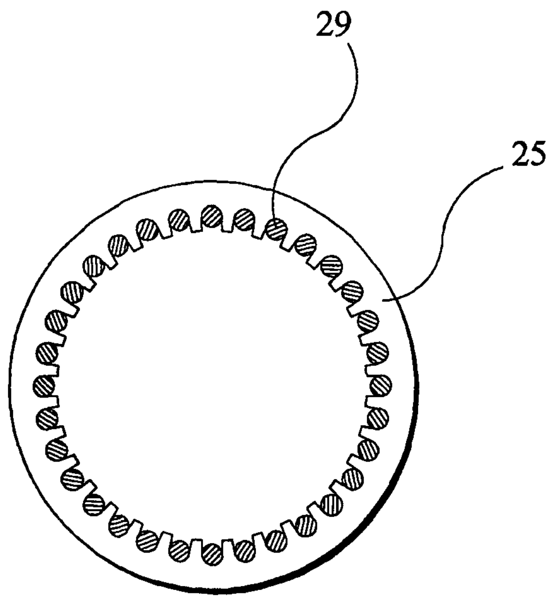


FIG 12

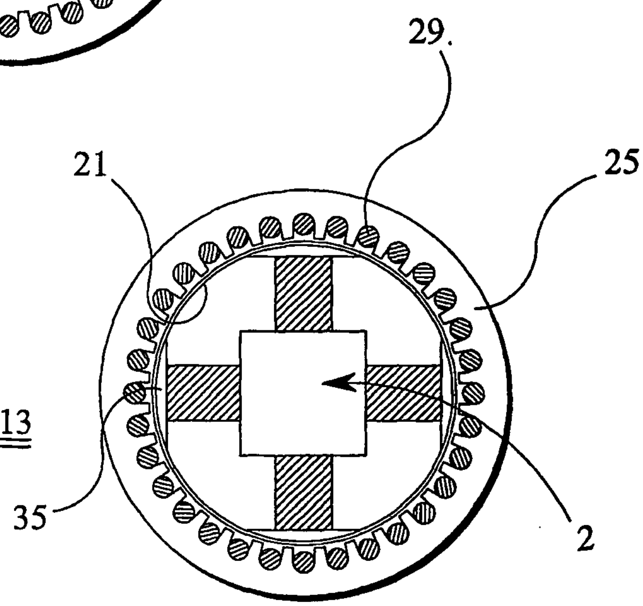


FIG 13

FIG 14

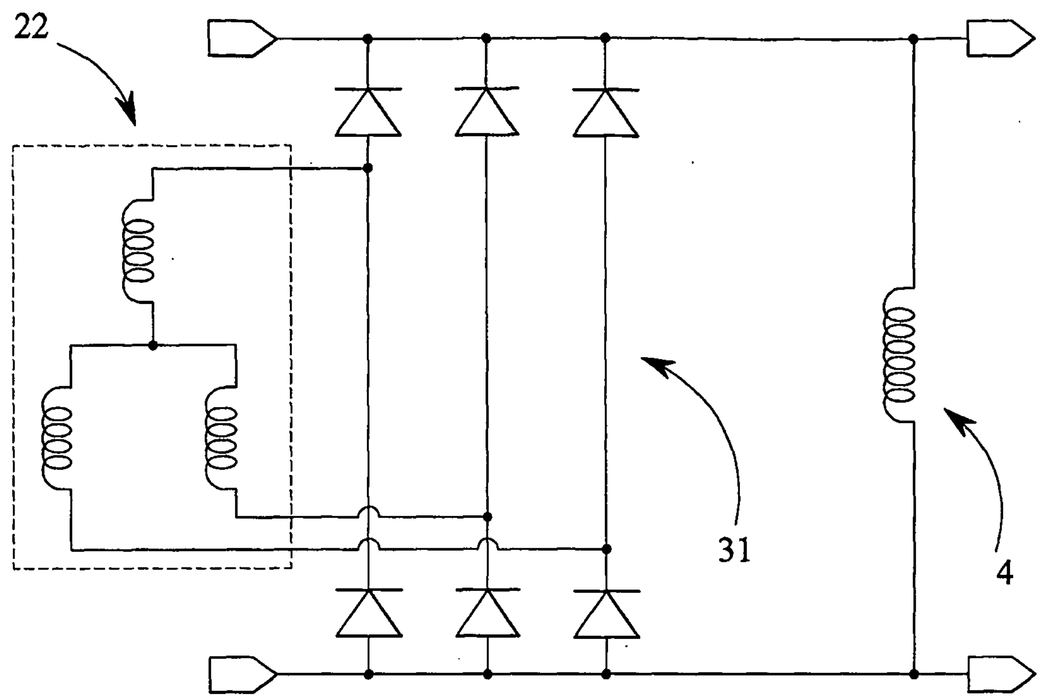
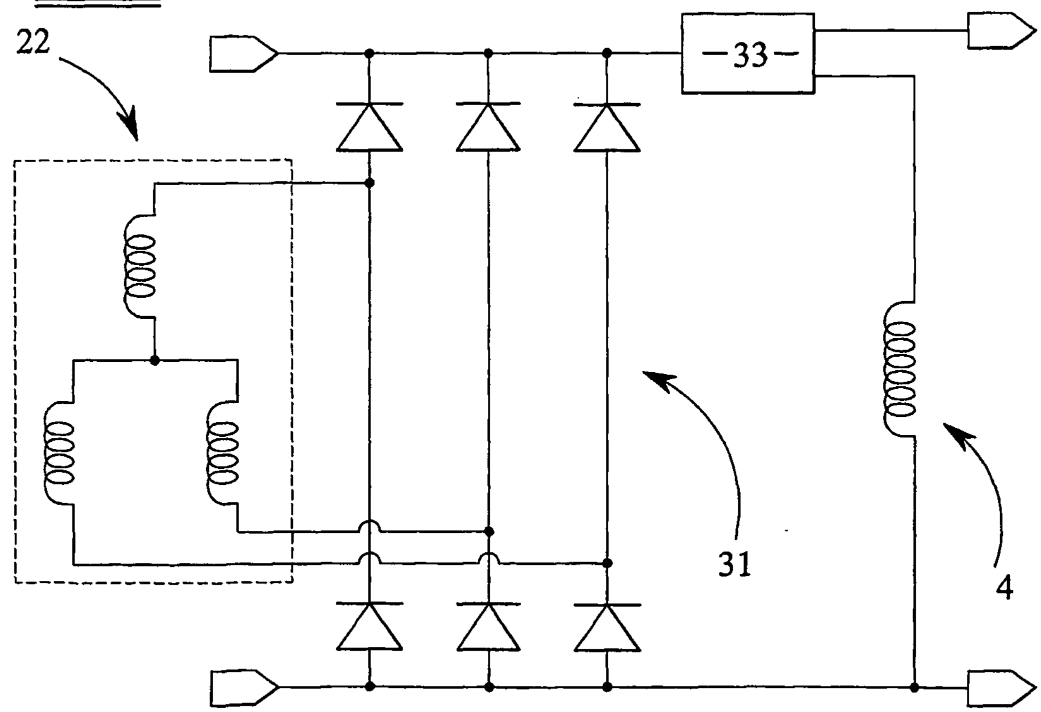


FIG 15



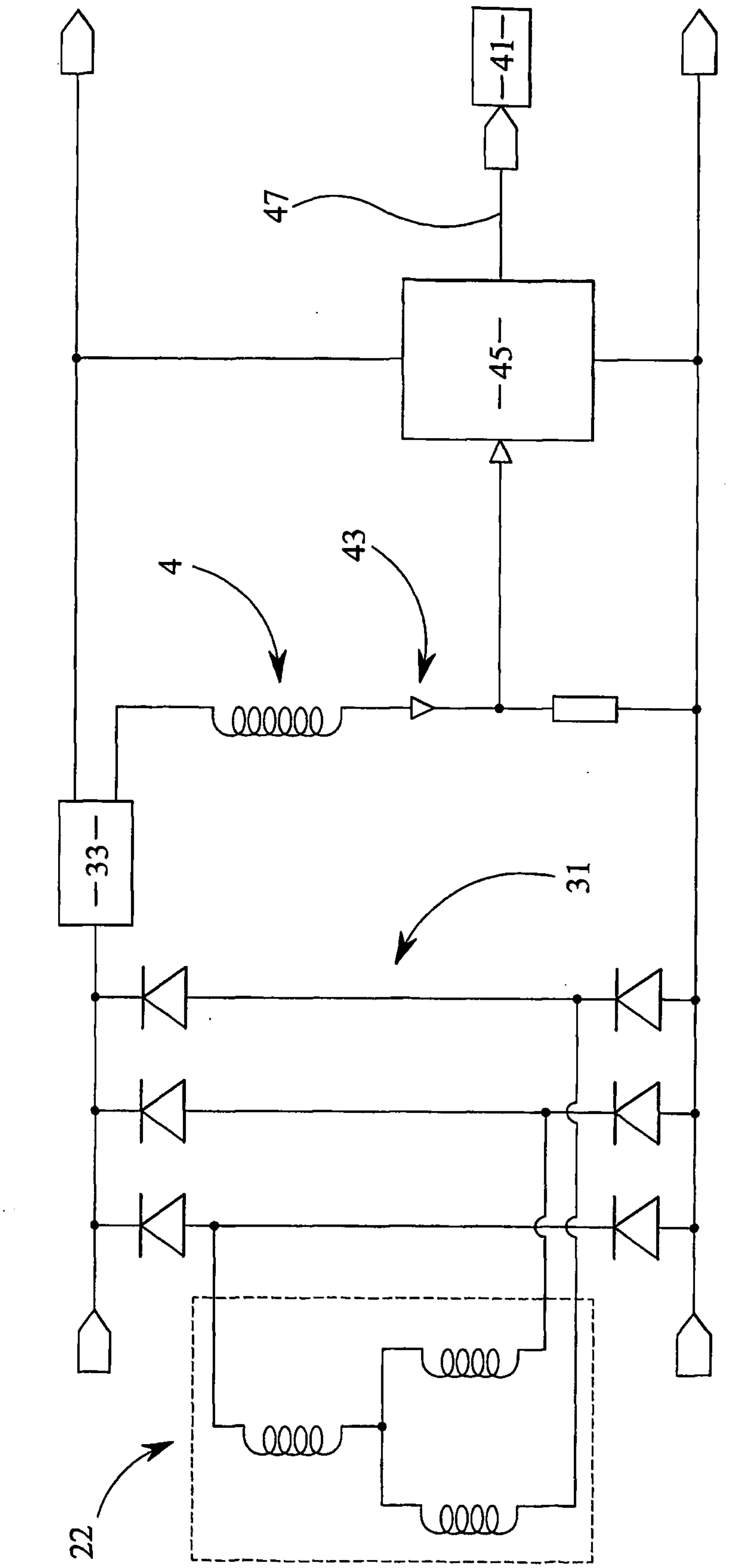


FIG 16

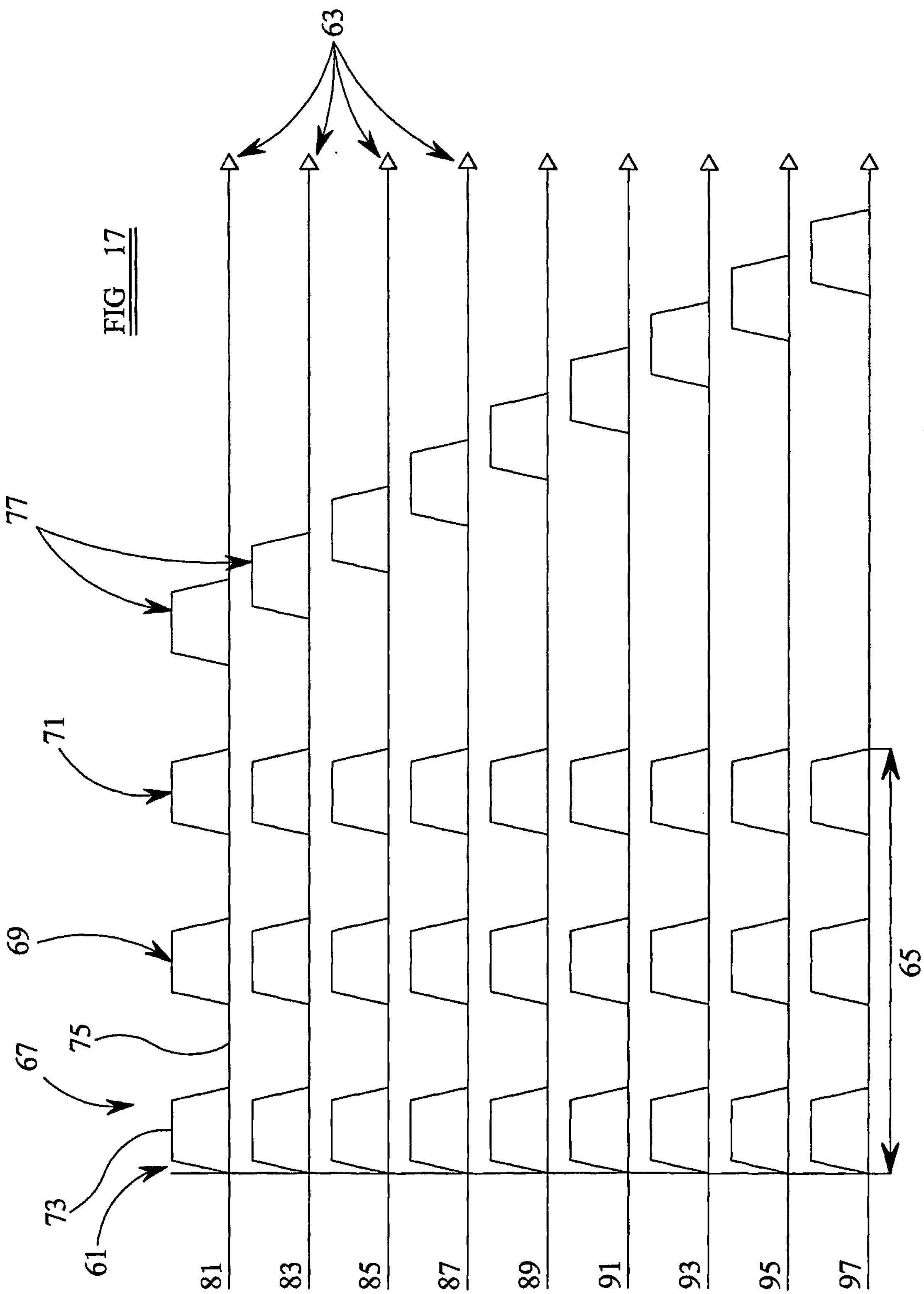


FIG 17

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB2004/000043

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H02P9/06 H02P15/00 E21B47/18 E21B41/00 H02K7/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 02/091553 A (SPRING GREGSON WILLIAM MARTIN) 14 November 2002 (2002-11-14) the whole document	1-14
Y	US 3 800 277 A (HARRELL J ET AL) 26 March 1974 (1974-03-26) column 5, line 40-48 column 6, line 33-47 figures 2,4	1-14
A	US 5 375 098 A (JOHNSON MIKE ET AL) 20 December 1994 (1994-12-20) column 15, line 51-68	1
A	US 6 191 561 B1 (BARTEL ROGER P) 20 February 2001 (2001-02-20) abstract	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

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Date of the actual completion of the international search	Date of mailing of the international search report
11 March 2004	26/05/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Schouten, A

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In   onal Application No
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